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TITLE OF THE INVENTION

METHOD FOR DRIVING AN ORGANIC ELECTROLUMINESCENT DISPLAY

DEVICE

5   BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a method for
driving an organic electroluminescent display device,
which uses an organic electroluminescent light emitting
10   element (hereinbelow, referred to as organic
electroluminescent element).

DISCUSSION OF BACKGROUND

An organic electroluminescent element has an organic
thin film provided between an anode and a cathode. The
15   organic thin film, which is sandwiched between both
electrodes, has unnegligible capacitance formed therein.
The organic electroluminescent element has properties
similar to semiconductor light emitting diodes. When the
anode side of the thin film is provided on a higher
20   voltage side, and when a certain voltage is applied
across both electrodes, the organic electroluminescent
element emits light. Conversely, when the cathode side
of the thin film is provided on a higher voltage side,
the organic electroluminescent element does not emits
25   light since almost no current flows. For this reason,
the organic electroluminescent element is also called an
organic light emitting diode in some cases.

When a constant voltage is applied across the thin film of an organic electroluminescent element, the luminance of the organic electroluminescent element greatly varies, depending on a change in temperature or a change with time. However, the width of variations in the luminance of an organic electroluminescent element is small with respect to the value of currents. In order to obtain required display intensity, it is common to use a constant-current drive wherein a constant-current circuit is provided in a driving circuit to supply a constant current to respective organic electroluminescent elements.

An organic electroluminescent display device, which has an organic electroluminescent element provided in each of pixels of matrix electrodes, is available. Fig. 9(a) and Fig. 9(b) are a schematic perspective view and a schematic cross-sectional view of the organic electroluminescent display device. There are provided a set of anode strips 2 connected to an anode or forming an anode per se, and a set of cathode strips 1 connected to a cathode or forming a cathode anode per se, which extend in a direction perpendicular to the anode strips. An intersection between a cathode strip 1 and an anode strip 2 forms a pixel, and an organic thin film 3 is sandwiched between both electrodes. In this manner, pixels, which are formed by organic electroluminescent elements, are provided in a matrix fashion and in a planar fashion on a glass substrate 4.

A technique for performing display of an organic
electroluminescent display device by passive matrix
addressing will be explained. In explanation below, one
of the set of the cathode strip 1 and the set of the

5   anode strip 2 works as scanning strips, and the other
works as data strips. Respective scanning strips are
connected to a scanning driver, which is provided with a
constant-current circuit. By this arrangement, constant-
current drive is performed with respect to the scanning

10   strips. The scanning strips are sequentially scanned so
that one of the scanning strips is in a selected state
with a selection voltage applied and the remaining
scanning strips are in a non-selected state without the
selection voltage applied. In general, the scanning

15   strips are sequentially scanned to have a certain drive
voltage applied thereto from the scanning strip at one
end of the set of the scanning strips to the scanning
strip at the other end so that one scanning strip has the
selection voltage applied thereto in every selection

20   period and so that all scanning strips are scanned in a
certain period.

The data strips are connected to a data driver,
which has a constant-current circuit provided at an
output stage. Display data, which correspond to the

25   display pattern of selected scanning strips, are supplied
to all data strips in synchronization with the scanning
of the scanning strips. A current pulse, which is

supplied to the data strips from the constant-current circuit, flows in a selected scanning strip through organic electroluminescent elements, which are located at the intersections between the selected scanning strip and the data strips.

The pixel of an organic electroluminescent element emits light only in a period wherein the scanning strip with that pixel connected thereto is selected and there is current supply from the data strip. When the current supply from the data strip stop, the light emission also stops. While a current supply is made to the organic electroluminescent elements sandwiched between the set of the data strips and the set of the scanning strips in this manner, all scanning strips are sequentially scanned in a repetitive fashion. In accordance with a desired display pattern, the emission and the non-emission of light is controlled with respect to the pixels of the entire display screen.

For driving the organic electroluminescent elements, the set of the anode strips 2 and the set of the cathode strips 1 of the organic electroluminescent elements may be set so that one of the sets works as the scanning strips or the data strips. In other words, the anode strips 2 are used as the scanning strips while the cathode strips 1 are used as the data strips. Or, the anode strips 2 are used as the data strips while the cathode strips 1 are used as the scanning strips. Both

sets of the electrodes have interchangeability in terms
of driving the organic electroluminescent elements.
Generally, it is common that the data scanning strips
correspond to the anode strips 2 and the scanning strips
5   correspond to the cathode strips 1. Hereinbelow,
explanation of the driving and the display of the organic
electroluminescent display device will be made about a
case wherein the cathode strips 1 works as the scanning
strips and the anode strips 2 work as the data strips.
10 In explanation below, the array of pixels that extend
parallel with the scanning strips will be also called
"row", while the array of pixels that extend parallel
with the data strips will be also called "column".

First, the scanning strips, which are connected to
15 the cathode for the organic electroluminescent elements,
need to satisfy the following electric potential
condition. Specifically, the potential of a scanning
strip in the selected state need to be lower than the
potential of a scanning strip in the non-selected state.
20 For the purpose, driving is performed so that the
potential of a scanning strip in the selected state is
set at ground (earth) potential so as to provide a
scanning strip in the non-selected state with a higher
potential than the ground potential.

25 The data strips on the column side are supplied with
a constant current when output data are turn-on data for
turning on a pixel. The data strips on the column side

are supplied with a constant voltage equal to ground

potential when output data are turn-off data for turning

off a pixel. In other words, the data strips are

configured so as to be switched between a constant-

5   current output and a constant voltage output, depending

on whether a pixel is turned on or off. The reason why

the data strips are supplied with the constant current

output is that the luminance is controlled by the value

of a current as stated earlier.

10   The direction of a current, which flows in an

organic electroluminescent element, is set so that the

current flows from the data strip as an anode strip 2 to

the scanning strip as a cathode strip 1 through the

organic thin film 3. For this reason, the potential of

15   the data strips is set so as to be higher than ground

potential as the potential of a scanning strip in the

selected state.

As shown in the equivalent circuit diagram of Fig.

10, organic electroluminescent elements exhibit not only

20   an electrical property as diodes but also a capacitive

characteristic. By supplying the current into a desired

pixel from the data driver having the constant-current

circuit, light is emitted from the pixel of an organic

electroluminescent element, which is in a row with the

25   selection voltage applied thereto. However, the pixels

that are in non-selected rows without the selection

voltage applied thereto simultaneously need to be

capacitively charged.

When the number of the pixels of an organic electroluminescent element, which are connected to one data strip, increases according to an increase in the

5   number of rows of the matrix forming a display screen, the current required for charging the capacitance of all pixels reaches an unnegligible value. As a result, the current that flows in a pixel in a row with the selection voltage applied thereto decreases to provide the

10 luminance with a lower value than the expected value.

In order to solve this problem, two driving methods have been proposed. A first method is reset driving. When driving is switched from one scanning strip to the next one, all scanning strips are set at an equal

15 potential once, and then charging is started at the equal potential for driving (e.g., JP-A-9-232074, paragraph 0024 to paragraph 0032 and Fig. 1 to Fig. 4).

The second method is precharge driving. A charging circuit is additionally provided on the data driver side,

20 and the respective pixels of an organic electroluminescent element are precharged for a certain time period. The luminance is improved by increasing the driving voltage for the organic electroluminescent elements (e.g., JP-A-11-45071, paragraph 0022 to

25 paragraph 0029 and Fig. 2).

Hereinbelow, previously setting all scanning strips at an equal potential once or previously charging the

respective pixels of an organic electroluminescent element will be referred to "the capacitive charge".

Fig. 12 shows a basic driving waveform in a case wherein the display pattern shown in Fig. 11 is displayed on a 4 × 4 matrix display screen having pixels positioned in columns C1, C2, C3 and C4 and in rows R1, R2, R3 and R4. Now, the driving method wherein the time width of an output current pulse from the data driver is modified will be explained.

As shown in Fig. 12, the current pulse is supplied so as to have a pulse width occupying substantially the full width of the selection period with respect to a pixel, which is required to emit light with the maximum luminance (a luminance of 100%). The current pulse is supplied so as to have a pulse width occupying a half width in comparison with the case of a luminance of 100% with respect to a pixel, which is required to emit light with a luminance of 50%. This driving method is called a pulse width modulation (hereinbelow, also referred to as PWM).

In the structure of an organic thin film 3 wherein a light emitting layer has a hole transport layer provided on the anode side of in layer, and wherein the hole transport layer and the anode have a hole injection layer interposed therebetween in layer, the hole injection layer may be made of copper phthalocyanine. It has been reported that the hole injection layer can be made of an

organic polymeric material to improve the property of an
organic electroluminescent display (e.g., JP-A-2000-
36390).

In the conventional driving methods, pixels are
5   actually driven after capacitive charge. When the
voltage that is applied to the pixels at the time of
completion of capacitive charge (charged voltage) fails
to reach the voltage that is applied to the data strips
at the time of driving a pixel (driving voltage), the
10   difference between the charged voltage and the driving
voltage causes a decrease in luminance in some cases.
Fig. 13(a) shows an example of the applied voltage, which
is applied to a pixel to emit light with a luminance of
100% or a luminance of nearly 100%. In Figs. 13(a) and
15   13(b), the time period for supplying a constant current
is indicated in the horizontal direction, and an applied
voltage is indicated in the vertical direction. The
rising edge of each applied voltage is the time when
capacitive charge has been completed.

20   When the charged voltage has the same value as the
driving voltage as shown in Fig. 13(a), selected pixels
have a desired current immediately flowing therethrough.
However, when the charged voltage is lower than the
driving voltage as shown in Fig. 13(b), other pixels in
25   the same column that are not selected also have a current
flowing therethrough even after completion of capacitive
charge until the applied voltage has reached the value of

the driving voltage. As a result, the pixels to emit
light are short of electric charges, lowering the
luminance. When the charged voltage is higher than the
driving voltage, the other pixels in the same column that

5   are not selected also have a current flowing out thereof
into the selected pixels even after completion of
capacitive charge. As a result, the selected pixels have
an excessive amount of electric charges, increasing the
luminance.

10   Since the cathode strips 1 have a certain level of
resistance, the amount of the current that flows into the
cathode strips varies depending on the number of pixels
to emit light per one row. As a result, the cathode
potential varies depending on the kind of a display

15 pattern. Even when pixels emit light with a relatively
high luminance, such as a luminance of 100% or a
luminance of nearly 100%, chrominance non-uniformity is
caused in a horizontally striped shape according to a
display pattern, depending on the kind of a display

20 pattern and the difference between the charged voltage
and the driving voltage, as shown in Fig. 14(b). This
type of display state is called horizontal cross-talk.
Fig. 14(b) shows a case wherein although an attempt is
made to turn off a portion of the display screen and emit

25 light from the remaining portions with a luminance of
100% as shown in Fig. 14(a), the luminance becomes darker
than expected since the cathode potential in a row having

a large number of pixels to turn on increases to prevent a certain current from flowing the organic electroluminescent elements forming the pixels to turn on.

When light emission is made with a low luminance by
5   PWM, the problem of horizontal cross-talk becomes a big issue. Figs. 15(a) and 15(b) show examples of the applied voltage for turning on a pixel by PWM. In Figs. 15(a) and 15(b), the time period for supplying a constant current is indicated in the horizontal direction, and
10   each applied voltage is indicated in the vertical direction.

When the charged voltage has the same value as the driving voltage as shown in Fig. 15(a), selected pixels have a desired current immediately flowing therethrough.
15   However, when the charged voltage has a different value from the driving voltage as shown in Fig. 15(b), other pixels in the same column that are not selected also have a current flowing therethrough even after completion of capacitive charge until the applied voltage has reached
20   the value of the driving voltage. When a pixel is energized to emit light with a low luminance as shown in Fig. 15(b), the time period for supplying a current to the relevant data strip ends before the applied voltage has reached the same value as the driving voltage. In
25   this case, the pixel emits light with a lower luminance than a desired luminance (required luminance). When all pixels have the same current-voltage characteristics in

an organic electroluminescent display device, the
luminance of the device uniformly lowers over the entire
screen. However, in a case wherein the pixels have
different current-voltage characteristics, the respective
5   pixels have different values of currents flowing
therethrough to fail to provide a uniform luminance over
the entire screen even when the pixels have the same
voltage applied thereacross. The current-voltage
characteristics of a pixel means the relationship between
10   a voltage applied to a pixel and a current flowing
through the pixel.

In a case wherein there are variations in the
current-voltage characteristics, i.e., wherein pixels
have different values of currents flowing therethrough by
15   application of a single voltage, a pixel emits light with
the required luminance and another pixel emits light with
a lower luminance in spite of that all pixels to emit
light are energized so as to emit light with the same
luminance by constant-current drivel. As a result, there
20   is caused chrominance non-uniformity wherein the
luminance varies to portion from portion to such degree
that can be visually recognized.

The degree of the horizontal cross-talk generated
becomes greater than a case wherein desired pixels are
25   energized to emit light with a luminance of 100% or a
relative high luminance near to a luminance of 100%.

When capacitive charge is performed to all pixels in

an organic electroluminescent display, additional power
is required for capacitive charge. Even when a display
pattern needs a small number of pixels to emit light, the
power consumption for the organic electroluminescent
5   display cannot be reduced to a lower value than the power
consumption required for capacitive charge.

SUMMARY OF THE INVENTION

It is an object of the present invention to solve
the problems stated earlier, to suppress the occurrence
10   of horizontal cross-talk or chrominance non-uniformity in
an organic electroluminescent display device and to
reduce the power consumption required for the organic
electroluminescent display device.

In order to attain the object, in a driving method
15   according the present invention, special drive for
capacitive charge, such as reset driving or precharge
driving, is not performed, a driving section is set so as
to have a shorter length than a selection period, and an
amount of electric charges, which are supplied to pixels
20   in the driving section in the selection period, is
controlled so as to correspond to required luminance. In
a driving method according the present invention, the
electric charges that have been accumulated in the
capacitance of the pixels in the driving period are
25   controlled to be supplied to selected pixels in a non-
driving period in the selection period. This form of
driving method will be referred to as the electric charge

control driving. When reset driving or precharge driving
is not performed, an amount of currents that flow through
the pixels is a period from start of drive to a time when
an anode voltage has achieved a driving voltage is small,

5   and the luminance is lower than an expected value in that
period as stated earlier. However, it is possible to
uniform the luminance amount in the selection period with
respect to required luminance by controlling an amount of
electric charges supplied to the pixels according to the

10   required luminance. Thus, it is possible to reduce
variations in luminance, and it is therefore possible to
suppress the occurrence of horizontal cross-talk.

According to a first aspect of the present invention,
there is provided a method comprising placing a data

15   strip in a high impedance state after supplying a
constant current to the data strip from a constant
current circuit in the selection period for applying a
selection voltage to a scanning strip, and providing an
organic electroluminescent element, the organic

20   electroluminescent element having luminous efficiencies
with respect to currents flowing therethrough falling in
a variation range in a range of voltages applied across
an anode and a cathode of the organic electroluminescent
element, the applied voltages ranging from a voltage

25   applied at end of a rising time of voltage application to
a voltage applied at end of the high impedance section in
the selection period. An example of the variation range

is 15%.

According to a second aspect of the present
invention, there is provided a method comprising placing
a data strip in a high impedance state after supplying a
5   constant current to the data strip from the constant
current circuit in the selection period for applying a
selection voltage to a scanning strip, performing
grayshade display by PWM, and supplying an amount of
electric charges to the data strip in a constant current
10 section when pixels emit light at respective gray scale
levels, the amount of electric charges being calculated
by adding an amount of residual electric charges to an
amount of electric charges corresponding to luminance
required for the respective gray scale levels, the amount
15 of residual electric charges being found based on an
estimated potential at the data strip at end of the high
impedance section. In accordance with the second aspect,
it is possible not only to obtain a desired luminance but
also to suppress the occurrence of chrominance non-
20 uniformity and horizontal cross-talk even in the case of
a low gray scale level.

In the method according to a third aspect of the
present invention, the method further comprises varying
the added amount of electric charges according to ambient
25 temperature of the organic electroluminescent element in
the second aspect.

In the method according to a fourth aspect of the

present invention, the organic electroluminescent element has luminous efficiencies to currents flowing therethrough falling in a variation range of 15% in a range of voltages applied across between an anode and a

5   cathode of the organic electroluminescent element, the applied voltages ranging from the voltage applied at end of the rising time to the voltage applied at end of the high impedance section in the selection period in any one of the first to third aspects. In accordance with the

10   fourth aspect, it is possible to obtain a uniform luminance even when the applied voltages greatly vary in the selection period.

In the method according to a fifth aspect of the present invention, the organic electroluminescent element

15   has a hole injection layer, which contains 50 wt% or more of organic polymeric material having a weight-average molecular weight of 1,000 or more in the fourth aspect. In accordance with the fifth aspect, it is possible to provide the electroluminescent element with a small

20   voltage-dependency in luminous efficiencies with respect to currents flowing therethrough.

In the method according to a sixth aspect of the present invention, the method further comprises setting a frame frequency at 120 Hz or lower and a duty ratio at

25   1/32 to 1/28, and setting a length of the high impedance section at (1/duty ratio)μs or longer in any one of the first to fifth aspects. In accordance with the sixth

aspect, one example of the range wherein the driving method according to the present invention can be effectively utilized is specified.

BRIEF DESCRIPTION OF THE DRAWINGS

5   A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings,

10   wherein:

Figs. 1(a) to 1(d) are schematic views showing electric charge control driving according to the present invention in comparison with conventional method;

Fig. 2 is a schematic view showing how electrodes

15   are provided in an organic electroluminescent display device;

Fig. 3 is a schematic view showing the driving portion for one column in a data driver and a pixel connected to the driving portion;

20   Fig. 4 is an explanatory view showing an example of the characteristics of an organic electroluminescent element having a small voltage-dependency in luminous efficiency;

Fig. 5 is an explanatory diagram showing an example

25   of the characteristics of an organic electroluminescent element containing copper phthalocyanine;

Fig. 6 is an explanatory diagram showing measurement

results for the relationship between a reached potential and the length of a high impedance time;

Fig. 7 is an explanatory diagram showing measurement results for the relationship between a reached potential

5   and a voltage at anode strips at the end of a constant current section;

Fig. 8 is an explanatory diagram explaining a range wherein the electric charge control driving can be effectively utilized;

10   Figs. 9(a) and 9(b) are a perspective view showing an organic electroluminescent display device and a cross-sectional view of the device respectively;

Fig. 10 is an equivalent circuit diagram of an organic electroluminescent element;

15   Fig. 11 is an explanatory diagram showing one example of a display pattern;

Fig. 12 is a waveform diagram showing one example of a driving waveform;

Figs. 13(a) and 13(b) are waveform diagrams showing

20   examples of voltages applied to a pixel according to conventional method;

Figs. 14(a) and 14(b) are explanatory diagrams showing how horizontal cross-talk is caused; and

Figs. 15(a) and 15(b) are waveform diagrams showing

25   examples of applied voltages when a pixel is energized so as to emit light by PWM according to conventional method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, an embodiment according to the present invention will be described, referring to the accompanying drawings. Figs. 1(a) to 1(d) are schematic

5 views showing the electric charge control driving according-to the present invention in comparison with conventional method. Fig. 2 is a schematic view showing how electrode strips are provided in an organic electroluminescent display device. Fig. 3 is a schematic

10 view showing the driving portion for one column in a data driver and pixels. In these figures, Figs. 1(a) and 1 (b) show the conventional method using PWM, and Figs. 1(c) and 1(d) show the electric charge control driving according to the present invention using PWM. In Figs.

15 1(a) to 1(d), "R" designates an idle period between a selection period and the next selection period. In Figs. 1(a) to 1(d), an upper half section shows the waveform of an output current from the data driver 4, and a lower half section shows the waveform of an anode voltage (the

20 waveform of a voltage of anode strips).

Referring to Fig. 2, the data driver 4 provides a constant current to anode strips 2 as data strips on driving, and a scanning driver 5 provides a selection voltage to cathode strips 1 as scanning strips to be

25 selected. As shown in Fig. 3, the anode strips 2 as the data strips can take any one of a state to be connected to a constant-current circuit 42, a state to be connected

to ground potential and a state to be disconnected from either one (a high impedance state), by a switching element 41. The anode strips are connected to ground potential only in the idle period. The driving period

5   for supply of a constant current and the time period in the high impedance state shown in Figs. 1(c) and 1(d) are called a constant current section and a high impedance section in some cases, respectively.

In the conventional driving method, when pixels are

10   energized to emit light with a luminance of 100% by passive matrix addressing, a selected pixel (a pixel connected to a cathode strip 1 with the selection voltage applied thereto) is provided with a constant current from the beginning to the end of a selection period after

15   completion of capacitive charge as shown in Fig. 1(a). When pixels are energized to emit light with a luminance of 50%, a selected pixel is provided with the constant current in a section occupying 50% of the selection period, and the anode strip 2 is at ground potential to

20   prevent the selected pixel from being energized in the remaining section occupying 50% of the selection period as shown in Fig. 1(b).

In accordance with the electric charge control driving, when pixels are energized to emit light with a

25   luminance of 100% by passive matrix addressing, the switch 41 is placed in the state to connect the constant-current circuit 42 and the anode strip 2 to provide a

selected pixel with a constant current in a certain
section in a selection period as shown in Fig. 1(c). In
the remaining section of the selection period, the switch
41 is placed in the state to disconnect the constant-

5   current circuit 42 and the anode strip 2 to place the
anode strip 2 in the high impedance state.

On the other hand, when pixels are energized to emit
light with a luminance of 50%, the switch 41 is placed in
the state to connect the constant-current circuit 42 and

10 the anode strip 2 to provide a selected pixel with the
constant current in a shorter section than the constant
current section shown in Fig. 1(c) to provide the
selected pixel with the constant current as shown in Fig.
1(d). In the remaining section of the selection period,

15 the switch 41 is placed in the state to disconnect the
constant-current circuit 42 and the anode strip 2 to put
the anode strip 2 in the high impedance state. The
potential of a selected cathode strip 1 is at 0V (ground
potential) as the selection voltage, and the potential of

20 the non-selected cathode strips 1 is at a higher
potential than the selection voltage.

When pixels are energized to emit light with a
luminance of 50%, the length of the constant current
section is set so that the amount of the electric charges

25 that pass through an organic electroluminescent light
emitting element in the selection period is half of the
amount of the electric charges that pass through the

organic electroluminescent light emitting element in the selection period when the pixels are energized to emit light with a luminance of 100%. In a case of a gray scale having any other luminance than a luminance 100% as well, the length of the constant current section is set so that the amount of the electric charges that pass through an organic electroluminescent light emitting element in the selection period decreases by the difference in comparison with the amount of the electric charges that pass through the organic electroluminescent light emitting element in the selection period when pixels are energized to emit light with a luminance of 100%.

In order to set the selection period in the electric charge control driving at the same length as the selection period in the conventional method, when the constant current section in the electric charge control driving is 1/2 of the constant current section in the conventional method, it is sufficient that the value of the current supplied from the constant-current circuit 41 is set to be substantially doubled in comparison with the value of that in the conventional method.

The electric charges that are supplied from the constant-current circuit 41 in the constant current section are accumulated in the capacitance of all pixels in one column, and the selected pixel allows the electric charges therein to pass therethrough according to its

diode characteristics. The selected pixel is energized to emit light by the electric charges passing therethrough. In the electric charges that have been accumulated in the capacitance of all pixels in one

5   column in the high impedance section pass through the selected pixel according to the diode characteristics of the selected pixel. Thus, the selected pixel continues to emit light even in the high impedance section.

On the assumption that the potential of the anode

10   strips 2 at the end of the selection period is V_{REST}, electric charges, the amount of which is determined by V_{REST} and the capacitance C_{colm} in one column, are expected to stay in the capacitance of the pixels in the one column. Hereinbelow, the amount of the electric charges

15   that stay in the pixels in one column at the end of the selection period is referred to as the residual electric charge amount. The amount of electric charges that have been supplied to one column from the constant current circuit 42 in the constant current section in the

20   selection period is referred to as the supplied electric charge amount.

Now, the reason why chrominance non-uniformity is reduced according to the electric charge control driving will be explained. Although the structure of an organic

25   electroluminescent display according to the present invention is basically similar to the structure of the conventional organic electroluminescent display shown in

Figs. 9(a) and 9(b), it is preferable that the organic
electroluminescent element used in the organic
electroluminescent display according to the present
invention has lesser voltage-dependence in luminous

5   efficiency to a passing current (emission
luminance/current density).

When the hole injection layer of the organic
electroluminescent element contains an organic polymeric
material, the organic electroluminescent element can have

10   a substantially constant luminescent efficiency
irrespective of a voltage applied to the pixels. Fig. 4
shows an example of the characteristics of an organic
electroluminescent element having less voltage-dependence
in luminous efficiency. Fig. 5 shows an example of the

15   characteristics of an organic electroluminescent element
having a hole injection layer made of copper
phthalocyanine. In each of Fig. 4 and Fig. 5, the
horizontal axis designates a voltage applied to the
pixels, and the vertical axis designates luminous

20   efficiency. In the characteristics shown in Fig. 4, the
degree of variations ((the maximum value - the minimum
value)/the minimum value) in the luminous efficiency is
less than 10% in a voltage range of 15V from 3 to 18V.
In general, the range from 3 to 18V may contain the range

25   of voltages, which are applied across the anode and the
cathode of an organic electroluminescence element in the
selection period (except the rising time of a voltage

applied to pixels in the selection period, i.e., the period that is required until the voltage across the anode and the cathode of the organic electroluminescent element has attained a substantially stable state.

5   As shown in Figs. 1(c) and (d), the voltage applied to pixels is not constant in the constant current section in the case of the electric charge control driving. However, the luminous efficiency becomes substantially constant irrespective of applied voltages by using an

10   organic electroluminescent element having the characteristics shown as an example in Fig. 4. That is to say, when the same amount of current flows in the selection period, the same amount of light emission can be obtained in the selection period irrespective of

15   applied voltages. In other words, a selected pixel emit an amount of light emission according to the amount of electric charges that have passed through the organic electroluminescent element in the selection period. Hereinbelow, the amount of electric charges that pass the

20   organic electroluminescent element is referred to as an element-passing electric charge amount. The element-passing electric charge amount means (the amount of supplied electric charges - the amount of residual electric charges).

25   When the amount of element-passing electric charges is constant in respective gray scale levels, the amount of light emission in the respective gray scale levels in

the selection period becomes constant. By setting the
amount of element-passing electric charges.according to a
difference in the gray scale levels, it is possible to
obtain a desired grayshade. The amount of supplied

5   electric charges can be easily set since the amount of
supplied electric charges is determined by the value of
an output current from the constant-current circuit 42
and the length of the constant current section. It is
difficult to control the amount of residual electric

10   charges. However, if it is possible to estimate V_{REST}, it
is possible to substantially accurately estimate the
amount of residual electric charges since it is easy to
see the capacitance C_{colm} in one column.

The amount of element-passing electric charges in

15   the respective gray scale levels may be determined based
on a required luminance for the respective gray scale
levels. When the amount of element-passing electric
charges and the amount of residual electric charges are
determined for the respective gray scale levels, it is

20   possible to make the amount of light emission constant in
the respective gray scale levels by setting the amount of
supplied electric charges at the value that is obtained
by adding the amount of residual electric charges to the
amount of element-passing electric charges, i.e., summing

25   the amount of residual electric charges and the amount of
element-passing electric charges. Thus, it is possible
to reduce chrominance non-uniformity. As a result, it is

also possible to reduce horizontal cross-talk. The
constant current section corresponding to an amount of
supplied electric charges, i.e., the driving pulse width,
may be represented by the following formula:

5   Driving Pulse Width =

       C_1 × required luminance of gray scale level + C_2

                                                    Formula 1

       In Formula 1, C_1 is a constant, and C_2 is equal to an
additional part (added part) corresponding to the amount
10 of residual electric charges. C_2 is a value dependent on
temperature and may vary depending on the ambient
temperature of an organic electroluminescent element.
Specifically, when the ambient temperature of an organic
electroluminescent element is high, C_2 may be decreased.
15 When the ambient temperature of the organic
electroluminescent element is low, C_2 may be increased.

       In some cases, the potential V_{drive} of the anode
strips 2 at the start of the high impedance section
varies because of, e.g., variations in the
20 characteristics of an organic electroluminescent element.
However, it is possible to obtain display on a display
screen in a uniform fashion irrespective of variations in
the potential V_{drive} by setting the high impedance section
so as to have a sufficiently long length. Fig. 6 is an
25 explanatory diagram showing measurement results for the
relationship between a reached voltage and the length of
a high impedance section (high impedance time) in a case

wherein an organic electroluminescent display device
using an organic electroluminescent element having the
characteristics shown in Fig. 4 was driven with a duty of
1/64 by the electric charge control driving. The reached
5   voltage means the potential of the anode strips 2. The
solid line in this figure designates measurement results
that were obtained when the potential V_{drive} of the anode
strips 2 at the end of the constant current section, i.e.,
the start of the high impedance section, was 14V. The
10   dotted line designates measurement results that were
.obtained when the potential V_{drive} was 16V.

The reached voltages gradually lower with lapse of
the high impedance time. Even in a case wherein V_{drive} at
the end of the constant current section varies, the
15   difference between reached voltages is made quite smaller
when the high impedance time as the length of a high
impedance section is about 70 µs. When the high
impedance time is beyond about 70 µs, the difference is
made further smaller.

20   Fig. 7 is an explanatory diagram showing measurement
results for the relationship between the potential of
anode strips 2 and a reached voltage at the end of a
constant current section in a case wherein an organic
electroluminescent display device using an organic
25   electroluminescent element having the characteristic
shown in Fig. 4 was driven with a duty of 1/64 by the
electric charge control driving, and the high impedance

time was set at 94 µs. As shown in Fig. 7, the reached
voltages at the end of the high impedance time of 94 µs
were almost constant irrespective of the voltages at the
anode strips 2 at the end of the constant current section.

5   Based on the measurement results shown in Fig. 6,
reached potentials may be regarded as being substantially
constant irrespective of variations in V_{drive} as long as
the high impedance time is beyond about 70 µs. For
example, a specific reached potential may be estimated as

10   being 7V based on the measurement results shown in Fig. 6.
The amount of the residual electric charges can be
calculated according to (reached potential × capacitance
in one column). In the case of an organic
electroluminescent display device using an organic

15   electroluminescent element having the characteristics
shown in Fig. 4, it is possible to estimate the amount of
residual electric charges unambiguously irrespective of
gray scale levels, and accordingly it is possible to
determine C_2 in formula 1 unambiguously. Thus, it is

20   possible to determine the amount of supply electric
charges, i.e., the drive pulse width that is appropriate
to the required luminescence for respective gray scale
levels. By setting the drive pulse width appropriately,
the amount of element-passing electric charges can have a

25   value appropriate to each of the gray scale levels,
suppressing chrominance non-uniformity in each of the
gray scale levels.

Now, the driving parameters that can effectively utilize the driving method according to the present invention will be described, referring to Fig. 8. In the case of a small duty, almost neither chrominance non-
5 uniformity nor horizontal cross-talk is caused even in a conventional method since the selection period can be lengthened. Specifically, in the case of a duty ratio of less than 1/32, the electric charge control driving is effective (see the straight line showing "Range wherein
10 invention can offer its advantages in sufficient fashion" in Fig. 8). Since it is impossible to determine the high impedance time so as to cover the entire range of the selection period, there are limitations to the high impedance time according to a utilized duty (see to the
15 curved line "Maximum value of high impedance time" in Fig. 8). Additionally, it is preferable that a section occupying at least about 20% of the selection period is allotted to the constant current section in the case of a frame frequency of 60 Hz for instant. From this
20 viewpoint, there are limitations to the high impedance time (see to the curved line "Minimum value of high impedance time" in Fig. 8).

In sum, the driving method according to the present invention can be effectively utilized in the hatched
25 region in Fig. 8. In other words, this region ranges from a duty ratio of less than 1/32 to a duty ratio of greater than 1/128 (an area on the left side with respect

to the duty ratio of 1/128 in Fig. 8) and from a high

impedance time occupying a length of greater than 0% of

the selection period to a high impedance time occupying a

length of not greater than 80% of the selection period.

5   In practice, it is preferable that the high impedance

time is not shorter than about (1/duty ratio) μs and

occupies a length of 80% or less of the selection period

as stated earlier. When the frame frequency is 120 Hz or

lower, the high impedance time may be set so as to occupy

10   1/2 of the selection period as long as the duty ratio is

greater than 1/64. When the frame frequency is 70 Hz or

lower, the high impedance time may be set so as to occupy

a length of 1/2 of the selection period as long as the

duty ratio is 1/84 or more.

15   In this embodiment, in order to drive an organic

electroluminescent display device by passive matrix

addressing, an organic electroluminescent element having

a small voltage-dependency in luminous efficiency is used

in the organic electroluminescent display device, and the

20   high impedance section is set following the constant

current section in a selection period as stated earlier.

By this arrangement, it is possible to reduce chrominance

non-uniformity and horizontal cross-talk in a low gray

scale level in the case of, in particular, PWM. In other

25   words, it is possible to improve display quality.

Although the degree of variations in luminous

efficiencies is 10% or less in the range of voltages

applicable to a pixel in the selection period as shown in
Fig. 4, it is conceivable that the electric charge
control driving can be practically utilized as long as
the degree of variations is about 15% in that range.

5   Additionally, it is possible to reduce power
consumption since capacitive charge is not performed.
This advantage becomes noticeable, in particular, when
the number of pixels to turn on is small, i.e., when the
ratio of pixels to turn on is low.

10   Now, examples of the electric charge control driving
will be shown.
EXAMPLE 1

An organic electroluminescent element for passive
matrix addressing was provided on a glass substrate.
15   Specifically, an ITO film was deposited on the glass
substrate so as to have a film thickness of 200 nm, and
the deposited film was etched to form anode strips 2. A
film of chrome (Cr) and a film of aluminum (Al) were
deposited so as to have a layered structure having a film
20   thickness of 300 nm, and the deposited layered structure
was etched to form wiring in the organic
electroluminescent element. On the etched structure,
photosensitive polyimide was applied as an insulating
film, and the applied film was exposed and developed to
25   form openings working as light emitting portions of
respective pixels. On the structure thus layered, a thin
film was deposited to form a hole injection layer as an

organic electroluminescent layer by a wet application
method using an organic solvent containing PTPDEK as an
organic polymeric material. PTPDEK is manufactured by
Chemipro Kasei Kaisha, Ltd. for example. The weight-
5   average molecular weight of PTPDEK is 1,000 or more. The
organic solvent needs to contain 50 wt% or more of PTPDEK.

Additionally, on the structure thus fabricated,
organic electroluminescent layers were layered by vapor
deposition. Specifically, for formation of a hole
10   transport layer, a film of α-NPD was deposited so as to
have a film thickness of 100 nm. Next, for formation of
a light emitting layer made of an organic luminescent
material, a film of Alq as a host compound and a film of
coumarin as a fluorescent pigment of a guest compound
15   were simultaneously formed so as to have a film thickness
of 30 nm by vapor deposition. On the light emitting
layer, a film of Alq was formed so as to have a film
thickness of 30 nm for formation of an electron transport
layer by vapor deposition, and a film of LiF was
20   additionally formed so as to have a film thickness of 0.5
nm as a cathode interface layer. Finally, a film of Al
was deposited to form scanning electrodes as the cathode
strips 1, and the scanning electrodes were connected to
cathode wiring. Next, in order to protect the organic
25   electroluminescent layers from moisture, an additional
glass substrate was provided so as to confront the glass
substrate stated earlier, both substrates were bonded by

a peripheral seal, a dry nitrogen gas was sealed in the portion encapsulated by the glass substrates and the peripheral seal.

5 The organic electroluminescent element thus fabricated was connected to a drive circuit to make an organic electroluminescent display device. The pixel arrangement was 96 (columns) × 64 (rows), and a pixel pitch was 0.35 mm × 0.35 mm. The organic electroluminescent display device was energized at a

10 frame frequency of 86 Hz and with a duty of 1/64 by the electric charge driving. The number of the gray scale levels was set at 16 (including a black level). An ML9361 product manufactured by Oki Electric Co., Ltd. was used as the data driver 4.

15 In the electric charge driving, the length of the selection period (selection time) was 182 μs, while the idle period was set at a length of 6 μs. As shown in Table 1, the driving current was 0.6 mA per one column. The current application section at the time of the

20 maximum gray scale level as the constant current section at the time of the maximum luminance was set to have a length of 98 μs. The current application section at the time of the minimum gray scale level except the black level was set to have a length of 11.5 μs. The luminance

25 at the time of the minimum gray scale level was smaller than 1/15 of the maximum luminance since a reverse gamma correction was taken into account. The high impedance

time as the length of the high impedance section at the time of the maximum gray scale level was set at 78 μs, i.e., 43% of the selection time. In this example, the added pulse width corresponding to C_2 in formula 1 was set at 10.8 μs.

The electric charge driving was performed under the conditions stated above. It was revealed that chrominance non-uniformity was not visually recognized and that no cross-talk was caused.

Table 1

	Example 1	Example 2
Driving method	Electric charge control driving	Electric charge control driving
Gray scale method	PWM	PWM
Driving current (mA/pixel)	0.6	1.2
Shortest high impedance time (μs)	78	127
Ratio of short high impedance time (μs)	43%	70%
Current application time at maximum gray scale level (μs)	98	49
Current application time at minimum gray scale (μs)	11.5	5.8
Added pulse width (μs): C_2	10.8	5.4
Results	Neither cross-talk nor chrominance non-uniformity	Neither cross-talk nor chrominance non-uniformity

EXAMPLE 2

The organic electroluminescent element used in Example 1 was also used and energized at a frame frequency of 86 Hz and with a duty of 1/64 by the electric charge control driving. The number of the gray scale levels was set at 16 (including a black level). As shown in Table 1, the driving current was 1.2 mA per one column. The current application section at the maximum gray scale level as the constant current section at the time of maximum luminance was set to have a length of 127s. The current application section at the minimum gray scale except the black level was set to have a length of 5.8 µs. The impedance time at the maximum gray scale level was set at 49 µs, i.e., 70% of the selection time. The added pulse width was set at 5.4 µs.

The electric charge driving was performed by the conditions stated above. It was revealed that chrominance non-uniformity was not visually recognized and that no cross-talk was caused.

COMPARATIVE EXAMPLE 1

The organic electroluminescent element used in Example 1 was energized by conventional reset driving. The frame frequency was set at 86 Hz, the duty ratio was set at 1/64, and the number of the gray scale was set at 16 (including a black level). As shown in Table 2, the driving current was 0.3 mA per one column, which is half of the driving current in Example 1.

In this case, horizontal cross-talk was recognized. In the case of an organic electroluminescent element that was fabricated as in Example 1 and had an unequal distribution in the driving voltages, chrominance non-uniformity was recognized at the time of a low gray scale. The unequal distribution in the driving voltages means that there are variations in the current-voltage characteristics of the pixels in an organic electroluminescent element.

Table 2

	Comparative Example 1	Comparative Example 2
Driving method	Reset driving	Electric charge control driving
Gray scale method	PWM	PWM
Driving current (mA/pixel)	0.3	0.4
Shortest high impedance time (μs)	0	29
Ratio of short high impedance time (μs)	0%	16%
Current application time at maximum gray scale level (μs)	176	147
Current application time at minimum gray scale (μs)	1.3	18
Added pulse width (μs): C_2	0	16.2
Results	Horizontal cross-talk was caused. Chrominance non-uniformity was caused at low gray scale in panel having unequal distribution in driving voltages	Horizontal cross-talk was caused. Chrominance non-uniformity was not caused.

COMPARATIVE EXAMPLE 2

The organic electroluminescent element used in Example 1 was also used and driven at a frame frequency of 86 Hz and with a duty of 1/64 by the electric charge control driving. The number of gray scale level was set at 16 (including a black level). As shown in Table 2, the driving current was 0.4 mA are one column. The current application time at the maximum gray scale level as the constant current section at the maximum luminance was set at 147s, and the current application time at the minimum gray scale level except the black level was set at 18 µs. Additionally, the high impedance time at the maximum gray scale level was set at 29 µs, i.e., 16% of the selection time. The added pulse width was set at 16.2 µs.

In this case, horizontal cross-talk was visually recognized, though chrominance non-uniformity was not recognized.

In accordance with the driving method of the present invention, it is possible to improve the display quality of an organic electroluminescent display device. It is also possible to reduce power consumption, in particular, when the ratio of pixels to emit light is small.

The entire disclosure of Japanese Patent Application No. 2002-350519 filed on December 2, 2002 including specification, claims, drawings and summary is incorporated herein by reference in its entirety.